A

RESEARCH PROPOSAL

ON

ATTENUATION STUDY OF MILLIMETER WAVE PROPAGATION THROUGH FOLIAGE IN DESERT

Submitted by

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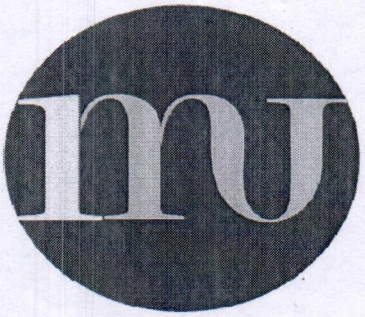

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ATTENUATION STUDY OF MILLIMETER WAVE PROPAGATION THROUGH FOLIAGE IN THE DESERT

1. INTRODUCTION

Frequencies above 10 GHz are subject to molecular absorption due to resonant frequencies of atmospheric molecules, water vapor and oxygen molecules offer maximum signal attenuation at 22GHz and 60GHz respectively. Because of small wavelength, the obstacles of the order of the wavelength being used cause signal attenuation. Foliage, sand/dust storms and rain are the major factors causing signal attenuation in propagation path. Attenuation due to sand/dust storms and rain depends upon the weather condition and are short in duration but the attenuation due to foliage is seasonally variable and stays for all the time. The size of leaves, the distribution of leaves, leaf density, branches and trunks, wind speed, dielectric constant and the height of the tree relative to the antenna heights are the factors that attenuate the signal when propagating through foliage. The tree leaves and branches also contain water and hence results in absorption and scattering of electromagnetic waves as they pass through it. When a signal scatters, traditional theory says that scattered field components are independent of each other. But by recent research, it is observed that if signal encounter on object which is collective in nature like foliage which consist of bunch of leaves and branches, scattered field components scatters in such a manner that there will be some in-phase components which interfere constructively to increase signal strength, the phenomenon is coherent scattering. According to Majeed and Tjuata (1996) Foliage not only introduces attenuation and broadening of the beam but also depolarization of the electromagnetic wave[22]. Seville (1997)Schwering(1998) and Godara (2015)observed that the attenuation due to foliage grows with frequency and it was also concluded that rate of attenuation decreases with foliage depth[1][2][23]. This decrement is due to coherent interference between scattered field components.Forestspossess a significant attenuation for operation of radio links in millimeter band in terms of absorption and scattering[26]. Reflection by foliage may also limits the use of millimeter wave for RADAR operation. Butin geographical region specifically Bikaner which is situated in the western part of Rajasthan, is under Thar desert of Indiawhere sand storm appears are in abundance butfoliage in traces, characterization of coherent and non-coherent part of scattered signal at foliage depthwill

be described with help of experimentaldata . It will be shown that the attenuation due to scattering in foliage depth at 35 GHz communications links operating in the frequency range shows coherency and it will be investigated. Simultaneously reflection by different foliage of desert to study behavior of millimeter wave will be done to ensure link reliability for RADAR systems. When wind blows there is some movement in foliage, so the effect of movement of foliage on millimeter wave propagation will be studied in western part of Rajasthan.

2. LITERATURE OVERVIEW

The signal propagation effects typically evaluated for communications links operating in the millimeter wave regime, the signal attenuation due to foliage is probably the most difficult to accurately quantify. The wide diversity in the types and density of foliage makes the estimate of attenuation highly variable. Most studies performed to date to quantify the impact of signal attenuation due to propagation through foliage have been concerned with horizontal propagation paths have only considered lower frequencies (upto 1.25 GHz) than the millimeter wave regime. In 1977 a simple analytical expression was proposed by Tamir [28] and it was valid upto 200MHz, above this frequency homogeneity of foliage layer is can not be assumed. Expression by Tamir is valid for Indian forests, experimentation by R. K Tewari, S. Swarup and Manujendra N Roy [27] validate it in year 1990 and also analyzed attenuation due to foliage at 50,200,500,800 MHz frequencies. Frequencies above 10GHz are subject to molecular absorption so it is very complex design a mode; for attenuation by foliage as foliage become no longer homogeneous. However, it is clear that foliage attenuation can severely degrade terrestrial communications in the millimeter regime regardless of the available link margin. Gary Comparetto in 1993 concluded that foliage is shown to be extremely imparting with signal attenuation of the order of 3 to 4 dB per meter of foliage [24]. The depth of the foliage to impart the attenuation, in 1968 by P.L.McQuateJ.M.Harmanthat is the attenuation per meter, is believed to decrease as the distance through foliage increases because some of the energy travels above the tree tops and is thus unaffected by the trees [29]. Weissberger proposed models for predicting the attenuation of radio waves by foliage in 1981[26]. In 1995 Seville, A. and K. H. Craig described an improved empirical model of the attenuation rates due to propagation through vegetation at millimeter wave frequencies known as maximum attenuation model (MA)[23]. In 1998 same decrement in rate of attenuation in foliage depth is justified with transport theory and

concept of coherent scattering by F.Schwering, E.Violette and R.Espeland for 9.6,28.8,57.6 GHz range of frequencies [2]. In year 2005, Feinian Wang, Kamal Sarabandi concluded that single scattering theory overestimates the millimeter wave attenuation through foliage, to improve accuracy multiple scattering model should be included for estimation of coherent attenuation. They achieved the accuracy of experimented results with distorted born approximation (DBA)[4].

In order to specifically quantify the amount of attenuation due to foliage presented in Thar Desert at 35 GHz North-West part of India is partially carried out by Godara and Rankawat in 2015 which is in agreement with previous research, further studies have to be carried out to define reflection, scattering by foliage desert at depth. The proposed empirical foliage loss analysis for the horizontal propagation path can be classified as the modified exponential decay (MED) models, such as Weissberger model [26], ITU Recommendation(ITU-R) model [30], COST235 model and Fitted ITU-R (FITU-R) model, the modified gradient model, such as Maximum attenuation(MA) model [23], Nonzero gradient (NZG) model [2], and Dual Gradient (DG) model. Microwave signals incident on dust particle in the atmosphere undergo both absorption and scattering, the degree of each being dependent upon the size, shape, and complex dielectric constant of the particles as well as the wavelength (or frequency) of the signal. A Rayleigh approximation is allowable when the size of the leaves and branches is very small with respect to the signal wavelength. The Rayleigh approximation technique was applied by Altshuler to generate the data for the signal attenuation due to dust (dB/km) as a function of operating frequency. Consequently, the Rayleigh approximation is valid to model signal attenuation in dust storms for operating frequencies in millimeter regime but not for foliage. For meteorological condition fog, behavior of 35 GHz signal is studied by Manisha and Godara in Thar desert in which results are in agreement with Asthular,s model [19].

From above literature, it can be concluded that as environmental condition changes attenuation by foliage varies. Above said different models are valid to a place but can be invalid for other as the refractive index of the atmosphere is a strong function of temperature and water content. LOS communications links however, may exhibit significantly larger signal attenuations due to multi-path fading phenomena resulting from the severe changes in the refractive index throughout the foliage region. The data generated from these experiments will be useful to adequately quantify the impact of signal attenuation on communications link performance. ISRO is also planning to

put a beacon operation at 20/30 GHz in future communication satellite. It is hoped that present study will throw some light in the field of research in designing a reliable terrestrial and satellite communication links in the Thar Desert.

3. RESEARCH GAP

For the establishment,a communication system in the millimeter wave band it becomes necessary to study the attenuation due to foliage. The communications in the millimeter wave regime through a dust laden communications path can be assured with adequate link design, but communications through any length of foliage was discouraged, even after that efforts are made to quantify the signal attenuation so the communication with any degree of confidence can be assured in a foliage environment. Studies of attenuation at millimeter wave due to foliage are done by various communication scientists with different environments and models are proposed according to their environmental conditions. In desert vegetation and foliage are fewer and humility is also less as compared with terrestrial or green lands. As attenuation causing factors are in limit, possibility of establishment of reliable communication system becomes more. Proposed research work will present the data which can be used for designing a reliable communication system using millimeter wave in Thar desert.

4. OBJECTIVES

1. To investigate the attenuation of millimeter wave in foliage depth with changing seasons.
2. To investigate the scattering of millimeter wave due to increasing size of canopies.
3. To investigate the attenuation behavior of millimeter wave through foliage in motion.
4. To investigate Statistical Path Loss of millimeter wave in desert region of Bikaner.
5. To study the reflection of millimeter wave by different kinds of foliage in desert region.

5. METHODOLOGY

In order to achieve above said objectives, an experimental setup available in Electronics and Communication Engineering Department, Government Engineering College Bikaner (Raj.) which consists of a line of sight (LOS) link operating at 35 GHz with PC interfaced spectrum analyzer will be used.

Following is the block diagram of experimental set-up-

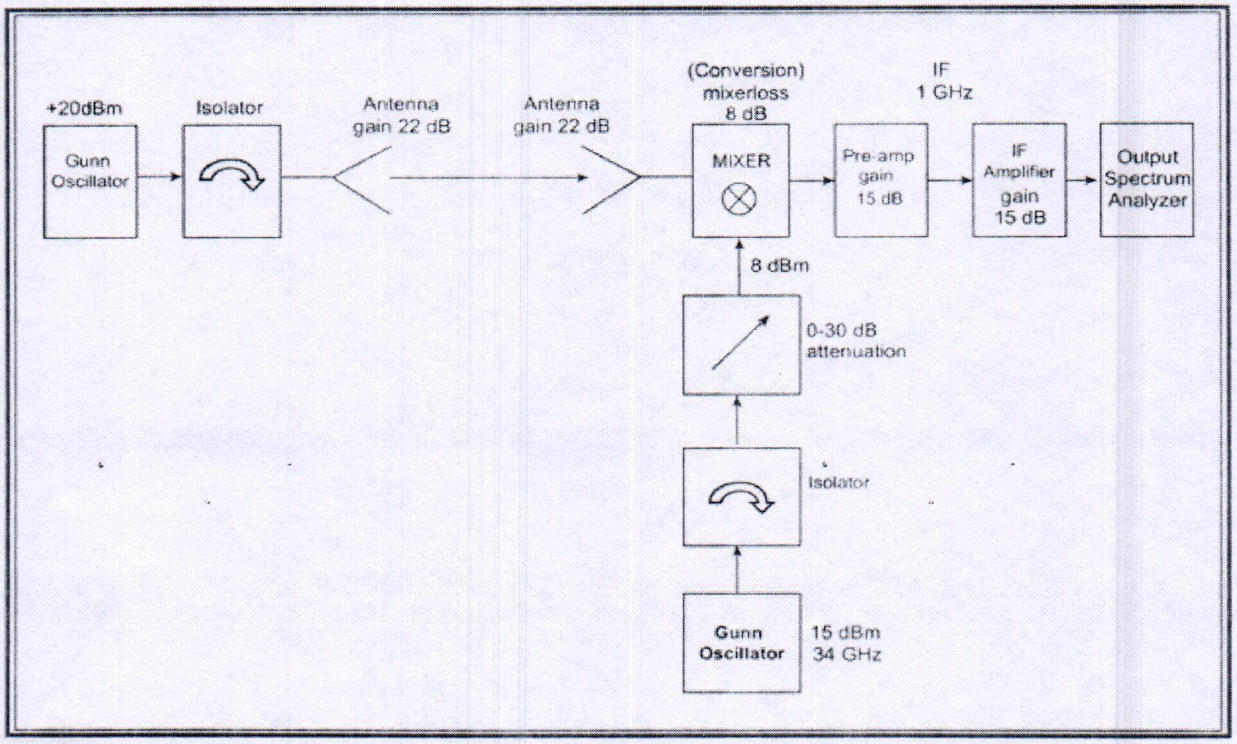

Fig 1. Block diagram of Communication link

At transmitting end, 35 GHz. signal generated by Gunn oscillator is fed to horn antenna through isolator. At the receiving end, signal received by horn antenna is given to the mixer in which second signal is locally generated 34 GHz. Resultant intermediate signal of 1 GHz. is then amplified and analyzed by spectrum analyzer.

OBJECTIVE WISE METHODOLOGY

5.1 To investigate the attenuation of millimeter wave in foliage depth with changing seasons

Methodology- For measurement of attenuation at foliage depth, campus of GECB have favorable tree line of *neem trees*(*Methaazadircta*). Neem Trees (*Methaazadircta)* are plantedon equal distance of 5 feets with each other and are of relatively same age and same canopy distribution with average leaf size of 5 cm in length and 1.5 cm in breadth are taken as attenuation measurement sight. Continuous planted trees are having average height of 5 meters with average trunk height of 2.7 meters. So, for attenuation measurement due to trunk, antenna height will be kept 1.86 meter and for canopy attenuation measurement antenna height will be taken 3.75 meters.

Attenuation measurement will be done in summer, autumn, winter and rainy seasons with following topology-

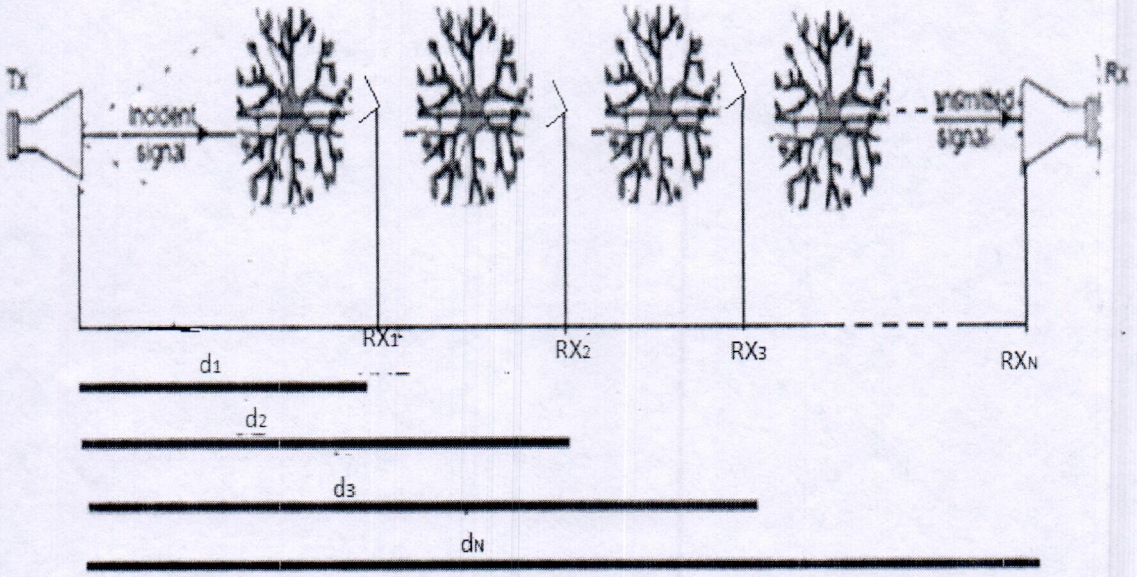

Fig. 2 Hardware positioning for attenuation measurement at foliage depth(Top-view)

5.2 To investigate the scattering of millimeter wave due to increasing size of canopies

Methodology- Scattering at different angles (30^0 to 330^0) with different canopy sizes will be carried out on *khejri trees* at campus of GEC, Bikaner.Following will be the topology for scattering measurement-

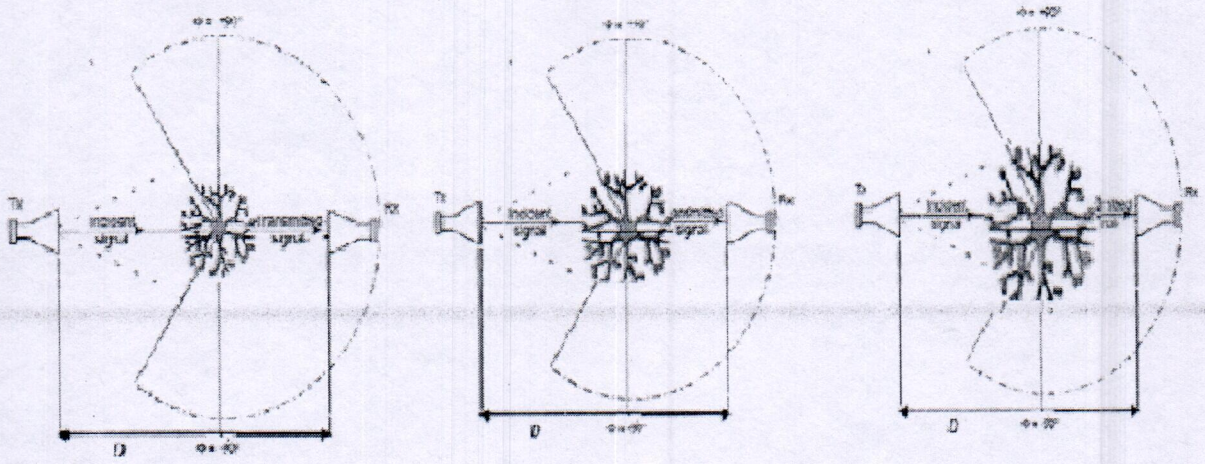

Fig. 3. Hardware position around foliage for Scattering measurement (top view)

Ten number of *Khejritrees* with increasing canopy sizes will be marked and radius of observation will be taken 2 meter bigger then radius biggest canopy(R_{max})among marked canopies. Then a circle will be drawn with radius R_{max}+2 meters around each canopy and position of transmitter will be fixed at some point on that circle. Then angles with difference of $30^0$with respect to transmitterwill be marked using theodolite and observationswill be taken by fixing receiver on the marked angles. Height of antenna will be taken such as it lies in mid of canopy height.This study is proposed to observe the scattering effects with foliage depth.

5.3 To investigate the attenuation behavior of millimeter wave through foliage in motion-

Methodology- Transmitter and receiver will be placed 10 meters apart. Observations will be taken for received power. Then a plant will be placed in between transmitter and receiver and received power will be observed to measure additional attenuation imparted by plant on millimeter wave. Then constant motion to the plant will be given using string and observations will be taken to quantify the effect of motion. Following will be the topology for attenuation measurement through foliage in motion-

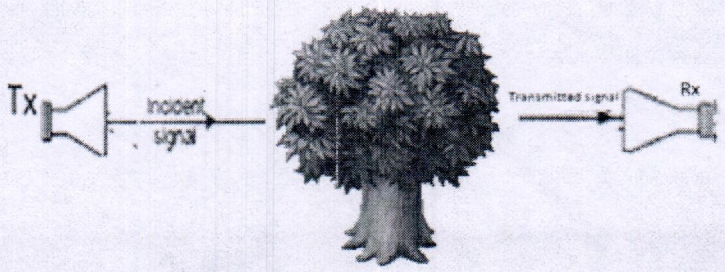

Fig.4. Hardware positioning for reflection Measurement(top-view)

5.4 To investigate Statistical Path Loss of millimeter wave in desert region of Bikaner-

Methodology- Antenna heightof transmitter and receiver will be set 1.8 meters following Fresnels zone criteria for clear line-of -site communication. Then observation for power received will be taken with separation distance between transmitter and receiver increasing with step size of 5 meters. Observations will be taken for 10 steps to investigate statistical path loss in desert region of western part of Rajasthan.

5.5 To study the reflection of millimeter wave by different kinds of foliage in desert region-

Methodology- Reflection studies will be done on *neem, seesam, peepal, khejri ,ber* . Approximately same size of trees will be marked and reflection measurement will be done using following topology-

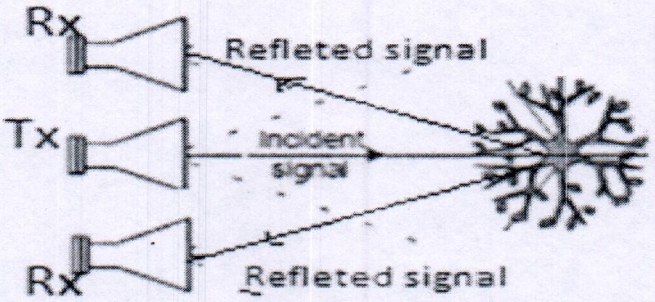

Fig.5. Hardware positioning for reflection Measurement(top-view)

Transmitter will be placed on distance two meter more from radius of canopy and receiver will be placed 15^0apart inleft and right directions from transmitter.

6. SIGNIFICANCE OF PROPOSED WORK

The presence of foliage in the propagation channel can lead to severe signal attenuation, and thus the effects of vegetation in the propagation environment need to be considered. Attenuation due to foliage has long been recognized as a major limitation to design reliable communication system and limits the use of higher frequency for line of sight (LOS) microwave links and high-speed data communication. But coherency, shown by field components at foliage depth gives some hope to make communication possible at millimeter wave. Data collected and analyzed during research can be used to generate algorithm to control the microwave link transmission

power so that in adverse conditions i.e. during maximum attenuation due to foliage with fog, it may transmit sufficient power to ensure reliable communication.

7. RESEARCH PLAN

Research work for study of attenuation in millimeter wave propagation through foliage in the desert will be done in following phases-

Phase I

Experimental Studies on

1. Initialization of experimental work with validation of link by drawing radiation pattern of horn antenna then investigation under foliage depth with horizontal polarization that can be carried out throughout the yearfor finding effect of four seasons (Summer and Rainy, Autumn and winter) on signal attenuation through foliage depth at North-west part of India.
2. Experimental work for desert foliage with increasing size trunks and canopies so as to conclude the scattering at various angles in northern Indiawith horizontal polarization.
3. Path loss studies (Free space attenuation) with changing seasons so as to define the effect of whether conditions on millimeter wave propagating in Thar desert.
4. Investigation under foliage depth with horizontal polarization that can be carried out throughout the Semester for finding effect of two seasons (Autumn and Winter) on signal attenuation through foliage depth at North-west part of India.
5. Investigation under different foliage *(Neem, Peepal, Ber, Khejri, Seesam*)for reflection behavior with horizontal polarization.
6. Investigation under moving foliage to find out the effect of movement on signal attenuation.

Phase II

Analysis of Experimental results

Conclusion

Phase III

Pre- Synopsis Viva

Dissertation work

Defense

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